3.0 RESULTS

3.1 Overview

Results of the biological evaluations indicated that the taxonomic assemblages for all communities were typical of what may be expected in southern Lake Michigan, especially with respect to the flooded beach zone habitat characteristic of the study area. Comparisons of community structure inside the dispersion zone with outside the dispersion zone using ANOVA statistical procedures resulted in few statistical differences. Statistically significant differences are shown as shaded boxes in Table 3-1, and include benthic richness and density, shore periphyton measures of diversity, phytoplankton richness, and float periphyton richness. The presence of statistically significant differences does not mean that ecologically significant, or biologically meaningful differences exist. The observed statistically significant differences appear to be attributed to biological responses to physical conditions rather than chemical effects from the Amoco Outfall 001 discharge. For example, Table 3-1 shows a statistically significant difference for benthos richness and density between inside the effluent dispersion zone and outside the dispersion zone. However, development of a benthic invertebrate community is severely limited in the beach zone habitat, such as the Amoco Cove, because of the naturally turbulent sandy substrates characteristic of this environment. The observed statistically significant difference reflects continuous turbulence from the discharge energy of Outfall 001 and Outfall 002 added to the intermittent turbulence normally observed in the shallow beach zone environment. These factors are likely to prevent the establishment and development of a benthic community at S120. Howmiller (see Snow 1970, pg. A-49) reports that in shallow waters near Bailly Indiana benthic macroinvertebrates were absent or present in low abundance, and states that:

> "This was attributed to the fact that most stations were on hard sand bottoms which, in shallow water and under periodically turbulent conditions, are a physically harsh environment. At only one station out of eight did a sample from a sand bottom in water less than 3 m depth contain benthic invertebrates."

The same conditions are present in the Amoco Cove.

TABLE 3-1

DATA SUMMARY CHART

Parameter	Is There Statistical Difference[1]	Is Difference Attributed to Effluent Constituents	Mean Parameter Value	
			Inside	Outside
Benthos				
Diversity Index-Shannon-Weiner	No		0.28	0.60
Diversity Index-Simpson's	No		0.60	0.67
Richness	Yes	No[a]	1.4	2.6
Density (organisms/M^2)	Yes	No[a]	122.1	1082.6
Evenness	No		1.00	0.84
Dominant Taxa Number-Hill's N1	No		1.4	1.8
Bray-Curtis PD Associations	No		1.00	0.52
Phytoplankton				
Diversity Index-Shannon-Weiner	No		2.11	2.06
Diversity Index-Simpson's	No		0.19	0.19
Richness	Yes	No[b]	34.7	27.8
Density (10^5 cells/L)	No		2.6	3.0
Evenness	No		0.62	0.62
Dominant Taxa Number-Hill's N1	No		8.4	8.0
Bray-Curtis PD Associations	No		0.22	0.34

1 Shaded entries denote that differences between community parameters inside and outside the effluent dispersion zone were statistically significant at the 95 percent confidence level.

a Reductions in benthos richness and density in the dispersion zone are attributed to additional turbulence and disruptive forces at the sediment surfaces from the discharge energy, further limiting the establishment of an already sparse benthic community.

b A review of the taxa suggested the increased phytoplankton richness within the dispersion zone consists of algae typically associated with sediments or attached to surfaces. The presence of this type of growth form in the plankton suggests a possible source of dislodged and resuspended periphyton (tychoplankton) from the nearby shoreline. Migration of tychoplankton from the shoreline into the local open waters commonly occurs, and the observed significant difference in richness is likely an artifact of proximity to the shoreline.

TABLE 3-1

DATA SUMMARY CHART

Parameter	Is There Statistical Difference[1]	Is Difference Attributed to Effluent Constituents	Mean Parameter Value	
			Inside	Outside
Zooplankton				
Diversity Index-Shannon-Weiner	No		0.51	0.74
Diversity Index - Simpson's	No		0.79	0.62
Richness	No		11.2	12.5
Density (# organisms/L)	No		21.9	15.5
Evenness	No		0.37	0.57
Dominant Taxa Number-Hill's N1	No		1.7	2.1
Bray-Curtis PD Associations	No		0.34	0.39
Float Periphyton				
Diversity Index-Shannon-Weiner	No		1.65	1.62
Diversity Index - Simpson's	No		0.18	0.17
Richness	Yes	No[c]	20.8	24.6
Density (10^5 cells/mm^2)	No		6.6	6.6
Evenness	No		1.41	1.20
Dominant Taxa Number-Hill's N1	No		5.3	5.2
Bray-Curtis PD Associations	No		0.14	0.31

1 Shaded entries denote that differences between community parameters inside and outside the effluent dispersion zone were statistically significant at the 95 percent confidence level.

c The reduction of algal periphyton richness on the site marker buoys within the effluent dispersion zone is likely an artifact of the increased current forces in the water column from the discharge energy. A difference of only 3.7 taxa during algal colonization periods without a concurrent difference in algal cell density is not biologically meaningful. Natural substrate available for algal colonization in the water column do not exist in the Amoco Cove.

TABLE 3-1

DATA SUMMARY CHART

Parameter	Is There Statistical Difference[1]	Is Difference Attributed to Effluent Constituents	Mean Parameter Value	
			Inside	Outside
Shore Periphyton				
Diversity Index-Shannon-Weiner	Yes	Uncertain[d]	1.89	1.54
Diversity Index - Simpson's	Yes	Uncertain[d]	0.13	0.19
Richness	No		7.5	5.5
Evenness	No		1.30	1.21
Dominant Taxa Number-Hill's N1	Yes	Uncertain[d]	6.6	4.7
Bray-Curtis PD Associations	Yes	Uncertain[e]	0.27	0.29
Epipsammon Periphyton[2]				
Diversity Index-Shannon-Weiner	No		2.42	2.37
Diversity Index - Simpson's	No		0.11	0.10
Richness	No		16.5	16.0
Dominant Taxa Number-Hill's N1	No		11.2	10.8
Algal Bioassay Test				
Final Chlorophyll-a (μg/L) *Scenedesmus quadricauda* *Selenastrum capricornutum*	 No No		 13.8 1.6	 14.1 1.2
Final Dry Weight (mg/L) *Scenedesmus quadricauda* *Selenastrum capricornutum*	 No No		 34.4 1.7	 36.9 2.3

1 Shaded entries denote that differences between community parameters inside and outside the effluent dispersion zone were statistically significant at the 95 percent confidence level.

2 Epipsammon periphyton based on 100 frustule counts.

d Differences in diversity measures between the shore periphyton collections are likely based on absence of *Bangia atropurpurea* at the Amoco Cove site. However, the observed differences in mean values for the diversity measures are biologically equivalent and should be considered negligible.

e Non-statistical evaluation based on mean PD values showing greater dissimilarity within each zone than between zones.

The Data Summary Chart (Table 3-1) presents sample evaluations and ANOVA statistical results for community structure parameter comparisons of samples collected inside the effluent dispersion zone and outside the dispersion zone. Appendix A presents a complete listing of the taxonomic assemblages and enumeration data. Appendix B contains graphical presentation of richness, diversity and density data for the benthos, phytoplankton, zooplankton and periphyton collections, and individual sample community summary descriptive statistics. Community summary statistics for biological samples from each site are presented and discussed below.

Other significant findings shown in Table 3-1 include the following:

- The sessile communities associated with substrates in the flooded beach zone were sparse. Excessive turbulence at the sediment surface effectively limited the establishment and development of a resident benthic community. The physical disruption was more apparent within the effluent dispersion zone but very low richness and diversity values were exhibited at all study stations.

- The phytoplankton exhibited a higher degree of community development than benthic community, and phytoplankton richness was significantly higher within the effluent dispersion zone than outside the dispersion zone. Taxa contributing to the higher richness within the effluent dispersion zone were characteristic of resuspended sediment associated algae and dislodged periphytic algae (tychoplankton). The logical source of periphytic and sediment associated algae is the shoreline, and the proximity of the effluent dispersion zone to the shoreline resulted in a large contribution of tychoplankton to the water column.

- Periphyton colonized on the sample site buoy markers showed a significantly higher species richness on floats from sites located outside the effluent dispersion zone than inside the effluent dispersion zone. Difference in mean taxa richness (3.7 species) is minimal, and was not accompanied by differences in density or large differences in taxonomic comparisons as shown by the Bray-Curtis PD Index. Richness differences were attributed to continuous disturbance from shoreline turbulence combined with discharge energy reducing the potential for colonization. Differences in richness indices are not biologically meaningful when not accompanied with density or taxonomic differences.

- Shore periphyton, dominated by the filamentous algal mat common to the shoreline region, were found at the Amoco Cove and the adjacent Whihala Beach Cove. Collections were conducted to evaluate the relative contribution of *Bangia atropurpurea* to the shore periphyton assemblage. Distribution and occurrence of *Bangia atropurpurea* is widespread in the Great Lakes, and has been suggested to be related to increased salinity in the Great Lakes. The matted filamentous algae at the shoreline in Amoco Cove did not contain *Bangia atropurpurea*. However, *Bangia atropurpurea* was a common component of the shore periphyton at Whihala Cove.

Ichthyoplankton (larval fish) sampling found no larval fish present. The lack of larval fish in the net collections can be considered common for late April collections. As explained by Dr. Darryl Snyder (Larval Fish Laboratory, Colorado State University) it is not uncommon for spawning to be delayed due to slow annual warming of the waters resulting from an extended winter or extensive winter freeze. The extremely cold winter of 1993-1994 may have contributed to a delay in spawning.

Algal bioassays using *Selenastrum capricornutum* and *Scenedesmus quadricauda* showed that no effects on algal growth in samples collected in the effluent dispersion zone. The test species were exposed to a series of ambient Lake Michigan water and mixtures representing the effluent dispersion zone and Lake Michigan receiving waters outside the dispersion zone. Statisfical tests (ANOVA) showed there were no effect of treatments using chlorophyll-a and dry weight. It is important to note that mixtures of 20:1 (Lake Michigan:treated effluent) had no effect on the algae. The proposed diffuser would achieve this ratio within seconds, and a few feet of the discharge pipe.

3.2 Benthos

Benthos samples collected from the study sites showed that the benthic community was poorly developed at all sample locations as demonstrated by low taxonomic richness values, and low Simpson's Diversity and Shannon-Weiner Diversity index values. A total of seven different benthic species representing Oligochaeta, Amphipoda, Diptera, and Mollusca were identified in the sandy substrates from the study sites. Richness ranged from zero organisms in some sample replicates (S120 and S340) to five taxa observed at S2000. *Limnodrilus* (Oligochaeta) was the most common benthic invertebrate and was frequently the most abundant organism present at any sample site. A complete taxonomic listing including organism abundance data for the benthos samples is presented in Appendix A. Table 3-2 shows mean values for selected community structure parameters determined from analysis of the collected samples.

Table 3-2. Benthos Community Structure Summary

Benthos Samples Community Summary Mean Values						
Parameter	Sample Sites					
	Dispersion Zone		Outside Dispersion Zone			
	S120	S340	S650	S1000	S2000	S3500
Richness	1.3	0.5	2.5	2.25	2.75	3.0
Simpson's Diversity	0.33	1.00	0.71	0.77	0.74	0.45
Shannon-Weiner Diversity	0.46	0.00	0.47	0.64	0.48	0.82
Evenness	1.00	1.00	0.67	0.62	0.61	1.47
Hill's N1 Dominant Taxa	1.67	1.00	1.64	1.48	1.75	2.41
N1 as percent of Richness	100.0	100.0	66.2	67.1	64.0	80.3
Density (# organisms/M^2)	66.60	177.6	1121	854.7	2024	312.1
Bray-Curtis PD-Each Zone	mean = 1.0		mean = 0.52			
Bray-Curtis PD-Between Zones	mean = 0.85					

No statistically significant effects from the effluent dispersion zone were found using ANOVA procedures on samples with the exception of benthos richness and density. Results indicated that benthic community richness, and mean organism density was significantly higher in samples collected outside the dispersion zone area. These differences are attributed to the effects of the discharge energy from Outfall 001 and Outfall 002 on the substrates within the effluent dispersion zone. The same forces that mix the effluent with Lake Michigan waters interact with the loose sandy substrates and create a physically turbulent habitat. Once the discharge energy has been dissipated, such as outside the effluent dispersion zone, the benthic community is limited by natural physical turbulence associated with the shallow flooded beach zone. The difference of less than 1.2 taxa for statistical significance associated with richness between inside the effluent dispersion zone (mean = 1.4 taxa) and outside the dispersion zone (mean = 2.6 taxa) reiterates that the benthic community was sparse at all sample sites. Table 3-2 shows that lowest mean density of 66.6 organisms/M^2 was observed within the dispersion zone at S120, and highest mean density of 2024 organisms/M^2 was observed outside the dispersion zone area at S2000. The mean density of organisms within the effluent dispersion zone (122.1 organisms/M^2) was statistically less than density outside the effluent dispersion zone (1083.5 organisms/M^2).

Differences in mean diversity and evenness of benthic organisms were not significant (Table 3-1). Graphical presentations of benthos richness, diversity, and density (mean, maximum and minimum values) at each sampling station are presented in Appendix B.

Benthic community comparisons using the Bray-Curtis PD index on species abundance data indicated that sites within the effluent dispersion zone (S120 and S340) were completely different (PD = 1.00). Mean PD value for site by site pairs from inside and outside the dispersion zone was were more similar (PD less than 1.00), indicating these benthic assemblages were more representative of each other than samples within the effluent dispersion zone alone. This suggests that differences in the benthic assemblage between the effluent dispersion zone and outside the dispersion zone cannot be detected (Table 3-1). A matrix of all PD values for each site comparison is presented in Appendix B.

3.3 Phytoplankton

The phytoplankton assemblage consisted of algae specimens considered true planktonic (unattached drifting) forms, and tychoplanktonic forms (dislodged and suspended algae cells which are commonly associated with substrates or loosely attached to submerged surfaces). The diatoms (Bacillariophyta) were the most abundant and richest algal forms in all samples. Phytoplankton richness ranged from 35 species at S650 (21 diatom taxa) to 48 species at S340 (29 diatom taxa). A total of 13 non-diatom algae taxa were identified including green algae, (Chlorophyta), blue-green algae (Cyanophyta), yellow-green algae (Chrysophyta), and the

Euglenophyta. A range of 3 to 5 different non-diatom algae were observed in each of the plankton samples. A listing of the diatoms and non-diatom algae is presented in Appendix A.

Phytoplankton diversity values ranged from a low of 1.81 at S3500 to 2.44 at S120 for the Shannon-Weiner Diversity index, and a low of 0.273 at S2000 to the most diverse community value of 0.224 at S120 for Simpson's Diversity index. Greatest mean diversity was exhibited at site S120. Density of the phytoplankton ranged from a low of 1.69 $X10^5$ cells/L at S2000 to a high of 6.44 $X10^5$ cells/L at S3500. Highest mean density of 3.54 $X10^5$ cells/L was seen at S3500. However, variation in density at S3500 nearly spanned the entire range observed from all sites. Table 3-3 shows mean values for the phytoplankton community structure parameters for each sample station.

No statistically significant differences were found for statistical comparisons (ANOVA) between phytoplankton community structure parameters (Table 3-1). Mean phytoplankton richness inside the dispersion zone (45.8 species) was significantly higher than mean species richness outside the dispersion zone (34.7 species; $F=51.8$, $F_{.05}=4.35$, $p<0.001$). The increased richness reflected the presence of algae that grow attached to surfaces in the near-shore samples (within the effluent dispersion zone). Nine of these taxa are typical of periphyhton assemblages and exhibit either prostrate attachment (*Achnanthes minutissima*, *Cocconeis placentula* var. *lineata*), and attached stalks or tubed growth forms (*Cymbella minuta*, *Gomphonema angustatum*), or taxa commonly associated with bottom substrates or other attached algae (*Nitzschia stagnorum*, *Surirella* species, some *Navicula* and *Synedra* species. These algae were not abundant outside the effluent dispersion zone. Dislodged or resuspended algae (tychoplankton) are commonly found in near-shore plankton samples. The sites in the effluent dispersion zone are sufficiently close to the local shoreline so that surface waves, currents, and discharge energy from Outfall 001 and Outfall 002 would easily dislodge and resuspend periphyton and epipsammon (sediment associated algae) into the water column. Phytoplankton from sites outside the effluent dispersion zone would also include tychoplankton, but the introduction and contribution of tychoplankton would be much greater closer to the source. Although two taxa (*Nitzschia* *stagnorum* and *Nitzschia frustulum*) which were observed from only the effluent dispersion zone are reported by Lowe (1974) to be obligate nitrogen heterotrophs. However, low relative abundance of these taxa inside the dispersion zone, and the presence of other *Nitzschia* species that are considered eutrophic indicators (*Nitzschia palea*, *Nitzschia kutzingiana*) indicates there are no nutrient effects from Outfall 001. No other community level parameter comparisons resulted in statistical significance.

Table 3-3. Phytoplankton Community Structure Summary

Phytoplankton Samples Community Summary Mean Values						
	Sample Sites					
	Dispersion Zone		**Outside Dispersion Zone**			
Parameter	**S120**	**S340**	**S650**	**S1000**	**S2000**	**S3500**
Richness	**35.25**	**34.25**	**26.00**	**29.67**	**30.25**	**25.50**
Simpson's Diversity	**0.16**	**0.21**	**0.18**	**0.19**	**0.21**	**0.18**
Shannon-Weiner Diversity	**2.23**	**2.01**	**2.16**	**2.05**	**2.02**	**2.06**
Evenness	**0.66**	**0.58**	**0.58**	**0.64**	**0.60**	**0.65**
Hill's N1 Dominant Taxa	**9.36**	**7.50**	**8.69**	**7.76**	**7.67**	**7.98**
N1 as percent of Richness	**54.91**	**44.79**	**47.47**	**50.93**	**42.32**	**50.83**
Density ($x10^5$ cells/L)	**2.79**	**2.39**	**3.22**	**2.98**	**2.28**	**3.54**
Bray-Curtis PD-Each Zone	**mean = 0.22**		**mean = 0.34**			
Bray-Curtis PD-Between Zones	**mean = 0.29**					

Results of the Bray-Curtis PD comparisons among samples within each zone, and between sample pairs from inside and outside the dispersion zone indicated taxonomically similar assemblages. The phytoplankton samples from within the effluent dispersion zone shows almost 80% similarity (PD = 0.22), and compared to the samples collected from outside the effluent